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(54) **METHOD FOR DETERMINING ESTIMATED VEHICLE DYNAMICS PARAMETERS**

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B62D 6/00 (2006.01)

(52) **U.S. Cl.** **701/41**

(58) **Field of Classification Search** 701/41
See application file for complete search history.

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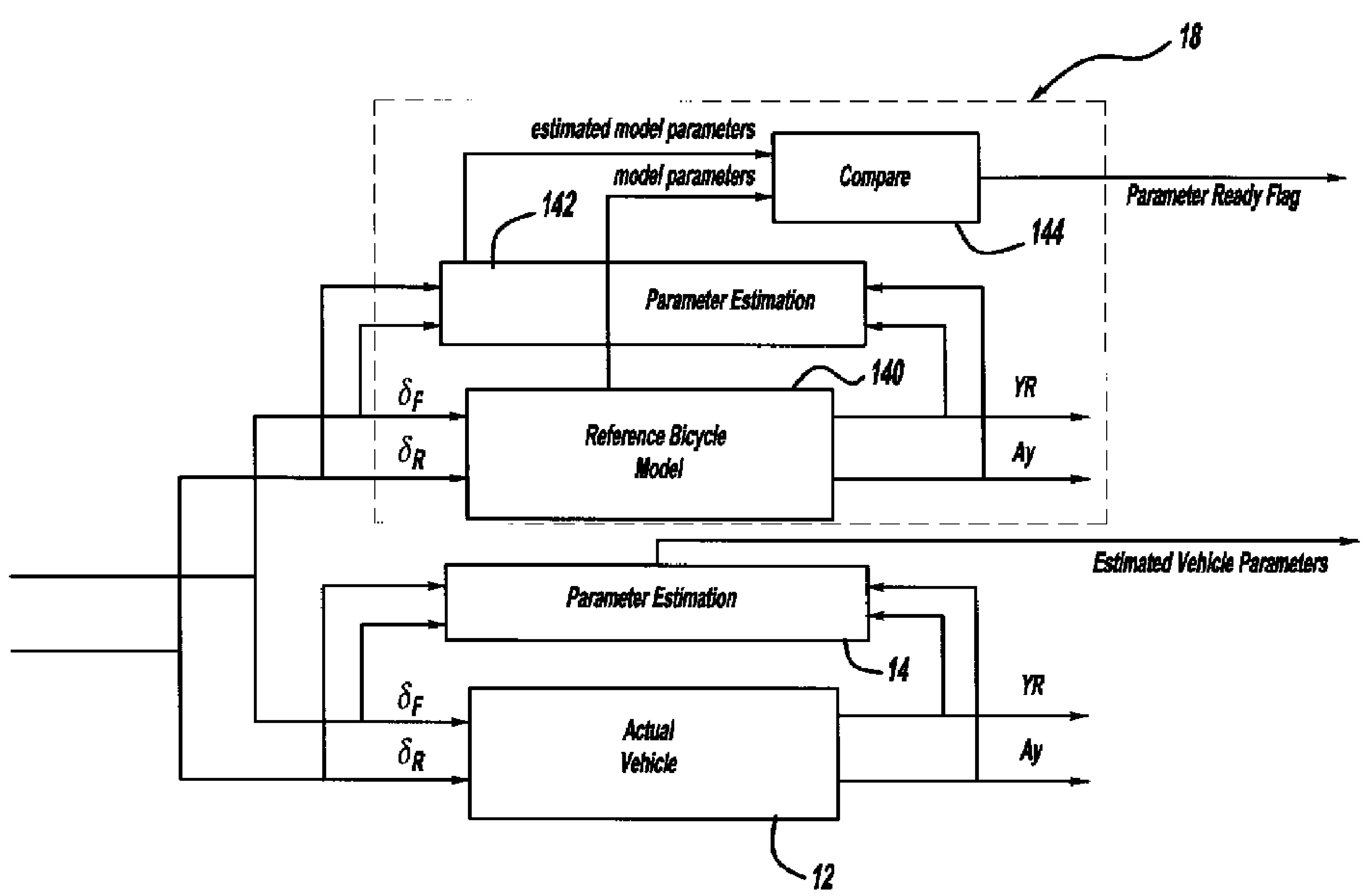
(57) **ABSTRACT**

A method for determining estimated vehicle dynamics parameters using a vehicle parameter estimator, a vehicle condition detector and a rich steering input detector for estimating vehicle understeer coefficient and front and rear cornering compliances in real time. The vehicle parameter estimator receives a front wheel steering angle signal, a rear wheel steering angle signal, a vehicle lateral acceleration signal, a vehicle yaw rate signal and a vehicle speed signal, and employs a linear parameter estimation algorithm for estimating the understeer coefficient, and the front and rear corning compliance. The vehicle condition detector receives the front wheel steering angle signal, the rear wheel steering angle signal, the vehicle yaw rate signal and the vehicle speed signal, and disables the vehicle parameter estimator if the vehicle is not operating in a linear region. The rich steering input detector determines whether the estimated vehicle parameters are reliable and are ready to be used.

13 Claims, 7 Drawing Sheets



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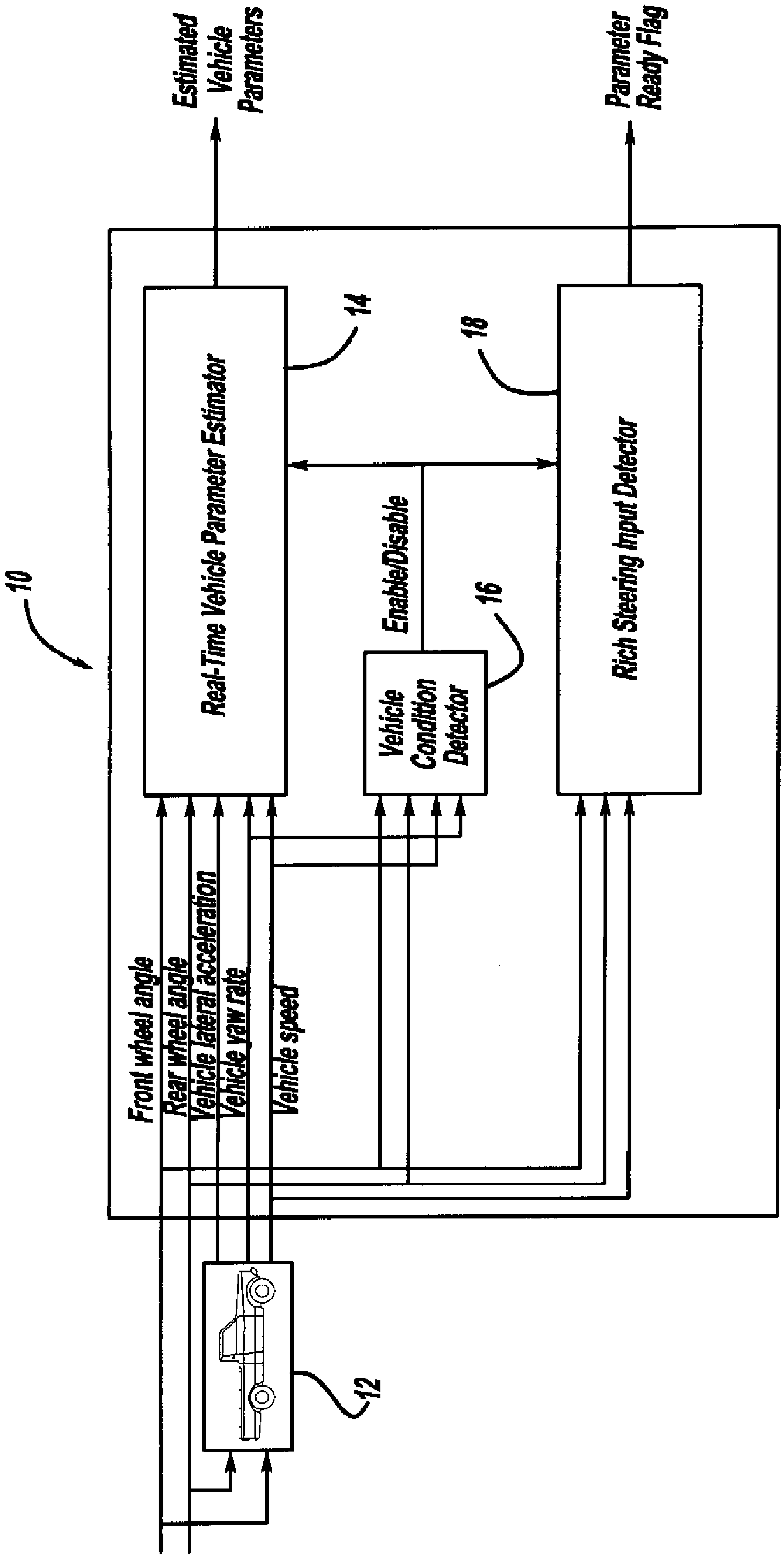
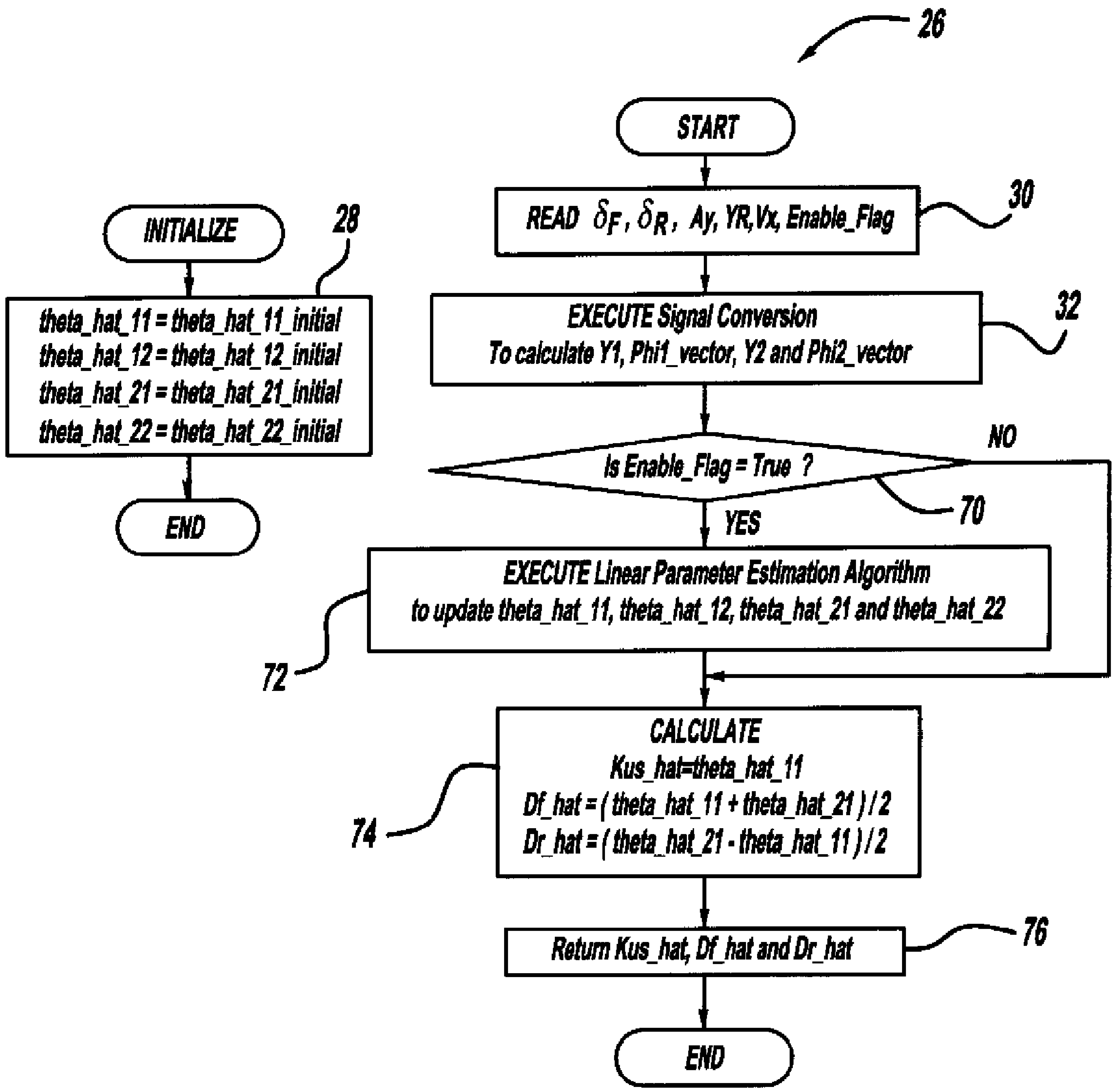

Estimated Vehicle Parameters
Parameter Ready Flag
Real-Time Vehicle Parameter Estimator
14
18
Enable/Disable
16
Vehicle Condition Detector
Rich Steering Input Detector
10
Front wheel angle
Rear wheel angle
Vehicle lateral acceleration
Vehicle yaw rate
Vehicle speed
12

FIG - 1



26
START
READ δ_F, δ_R, Ay, YR,Vx, Enable_Flag
30
EXECUTE Signal Conversion
To calculate Y1, Phi1_vector, Y2 and Phi2_vector
32
Is Enable_Flag = True ?
NO
YES
70
EXECUTE Linear Parameter Estimation Algorithm
to update theta_hat_11, theta_hat_12, theta_hat_21 and theta_hat_22
72
CALCULATE
Kus_hat=theta_hat_11
Df_hat = (theta_hat_11 + theta_hat_21) / 2
Dr_hat = (theta_hat_21 - theta_hat_11) / 2
74
Return Kus_hat, Df_hat and Dr_hat
76
END
INITIALIZE
28
theta_hat_11 = theta_hat_11_initial
theta_hat_12 = theta_hat_12_initial
theta_hat_21 = theta_hat_21_initial
theta_hat_22 = theta_hat_22_initial
END

FIG - 2

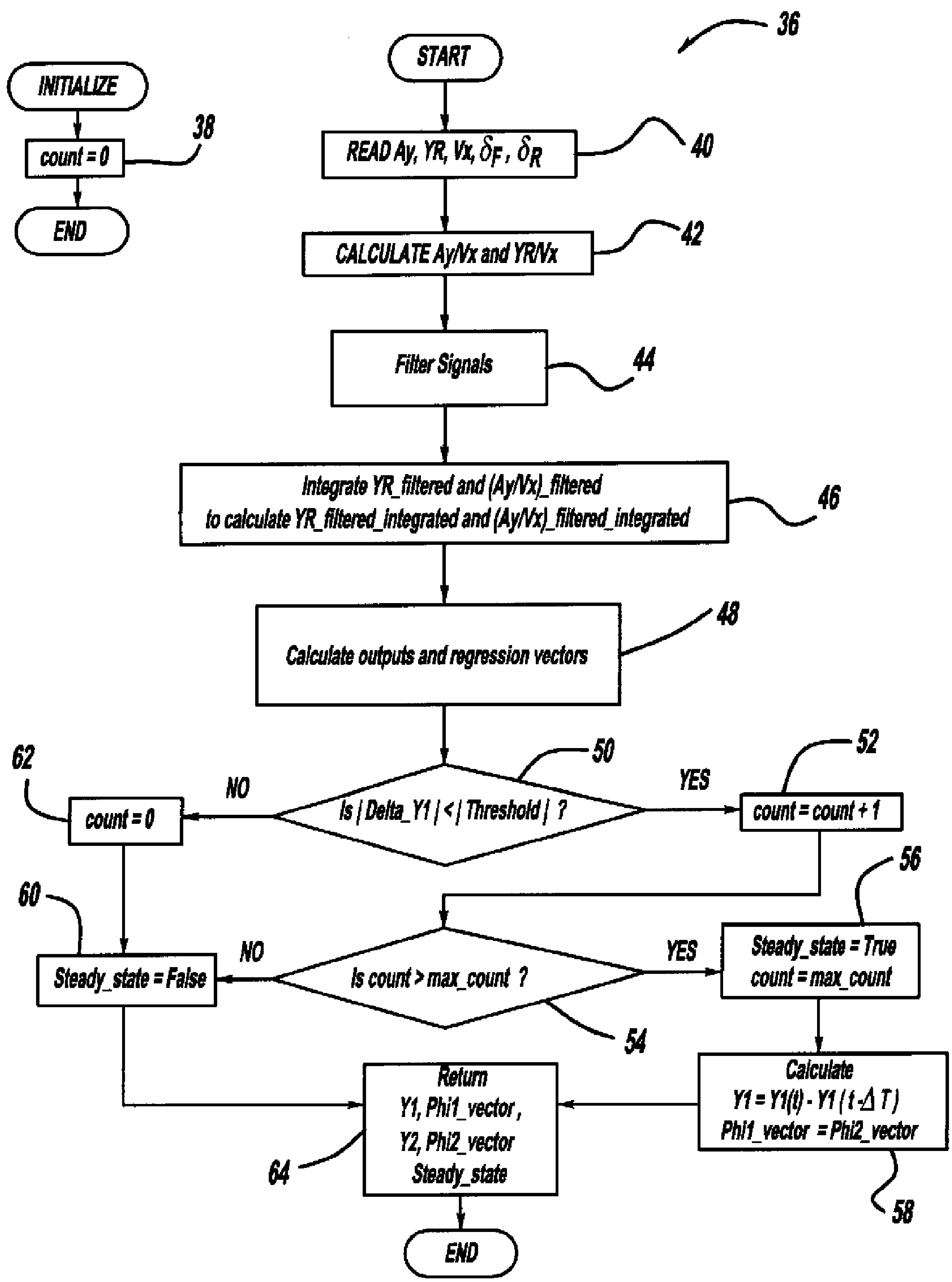
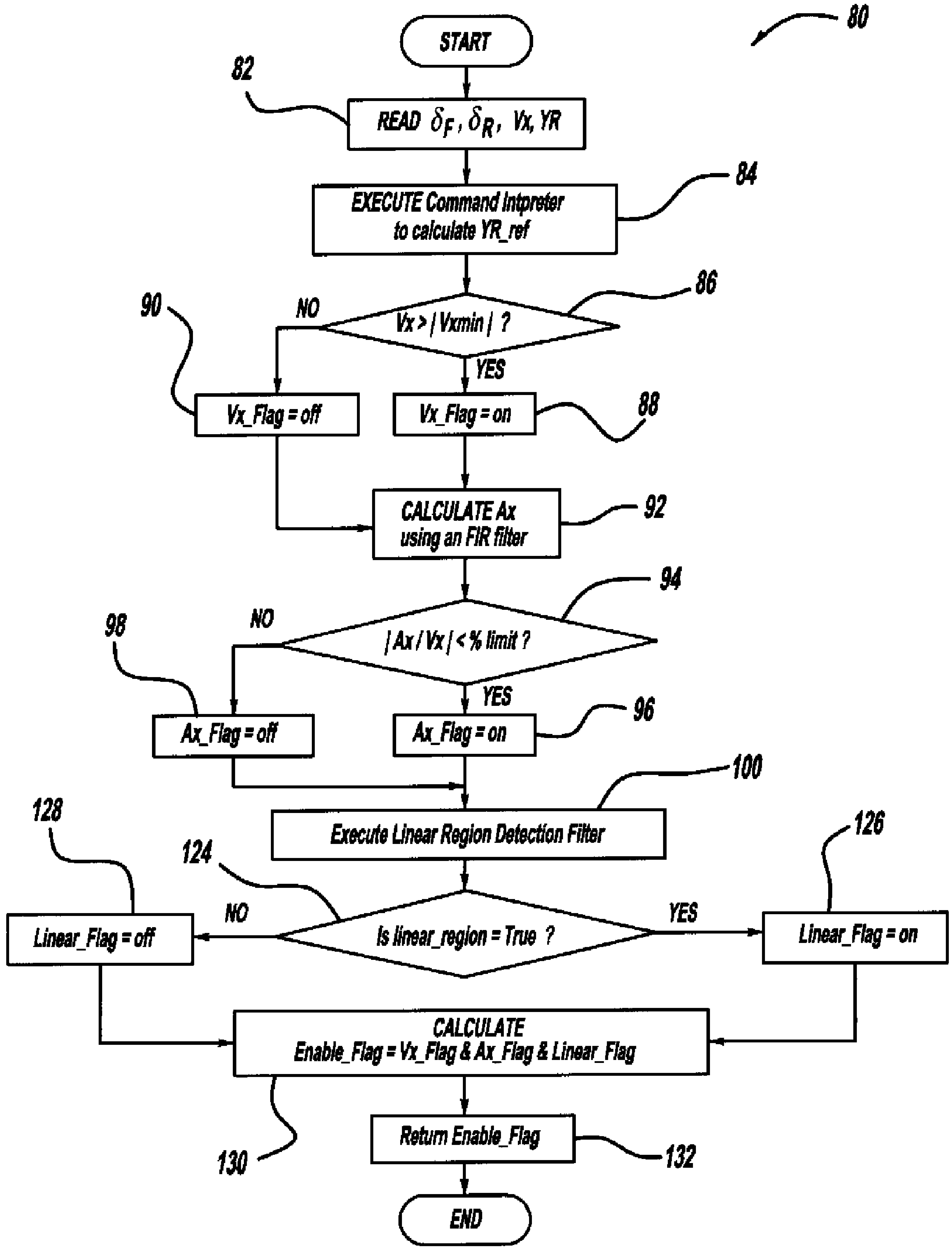

36
INITIALIZE
count = 0
38
END
START
READ Ay, YR, Vx, δ_F, δ_R
40
CALCULATE Ay/Vx and YR/Vx
42
Filter Signals
44
Integrate YR_filtered and (Ay/Vx)_filtered
to calculate YR_filtered_integrated and (Ay/Vx)_filtered_integrated
46
Calculate outputs and regression vectors
48
62
count = 0
NO
Is | Delta_Y1 | < | Threshold | ?
50
YES
count = count + 1
52
56
60
Steady_state = False
NO
Is count > max_count ?
YES
Steady_state = True
count = max_count
54
Return
Y1, Phi1_vector,
Y2, Phi2_vector
Steady_state
Calculate
Y1 = Y1(t) - Y1 (t-Δ T)
Phi1_vector = Phi2_vector
64
58
END

FIG - 3



80
START
82
READ δ_F, δ_R, Vx, YR
84
EXECUTE Command Intpreter
to calculate YR_ref
86
Vx > | Vxmin | ?
NO
YES
90
Vx_Flag = off
Vx_Flag = on
88
CALCULATE Ax
using an FIR filter
92
94
| Ax / Vx | < % limit ?
NO
YES
98
Ax_Flag = off
Ax_Flag = on
96
100
Execute Linear Region Detection Filter
128
124
126
Linear_Flag = off
NO
Is linear_region = True ?
YES
Linear_Flag = on
CALCULATE
Enable_Flag = Vx_Flag & Ax_Flag & Linear_Flag
130
Return Enable_Flag
132
END

FIG - 4

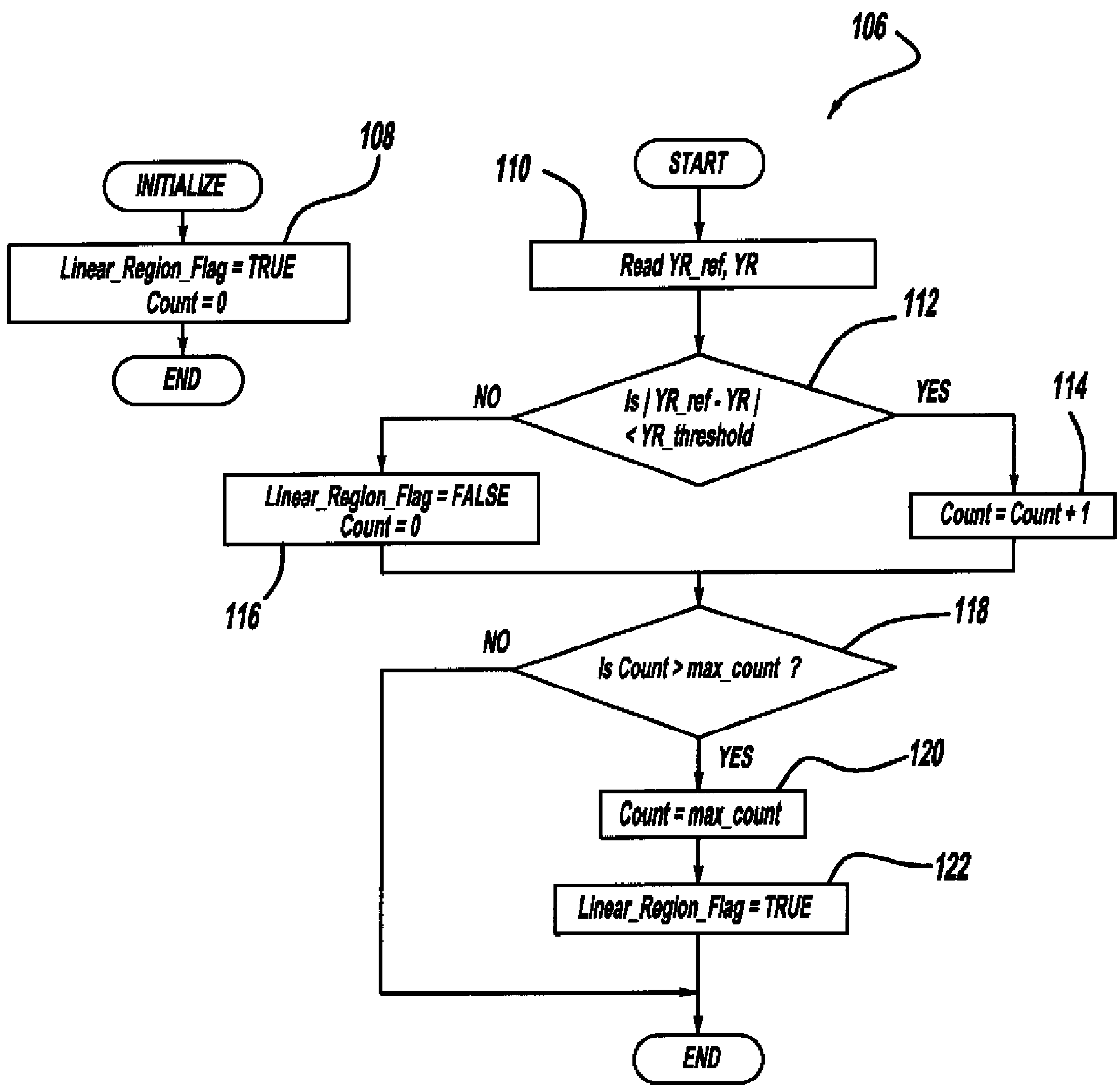

106
108
INITIALIZE
Linear_Region_Flag = TRUE
Count = 0
END
110
START
Read YR_ref, YR
112
Is | YR_ref - YR |
< YR_threshold
NO
YES
114
Linear_Region_Flag = FALSE
Count = 0
Count = Count + 1
116
118
NO
Is Count > max_count ?
YES
120
Count = max_count
122
Linear_Region_Flag = TRUE
END

FIG - 5

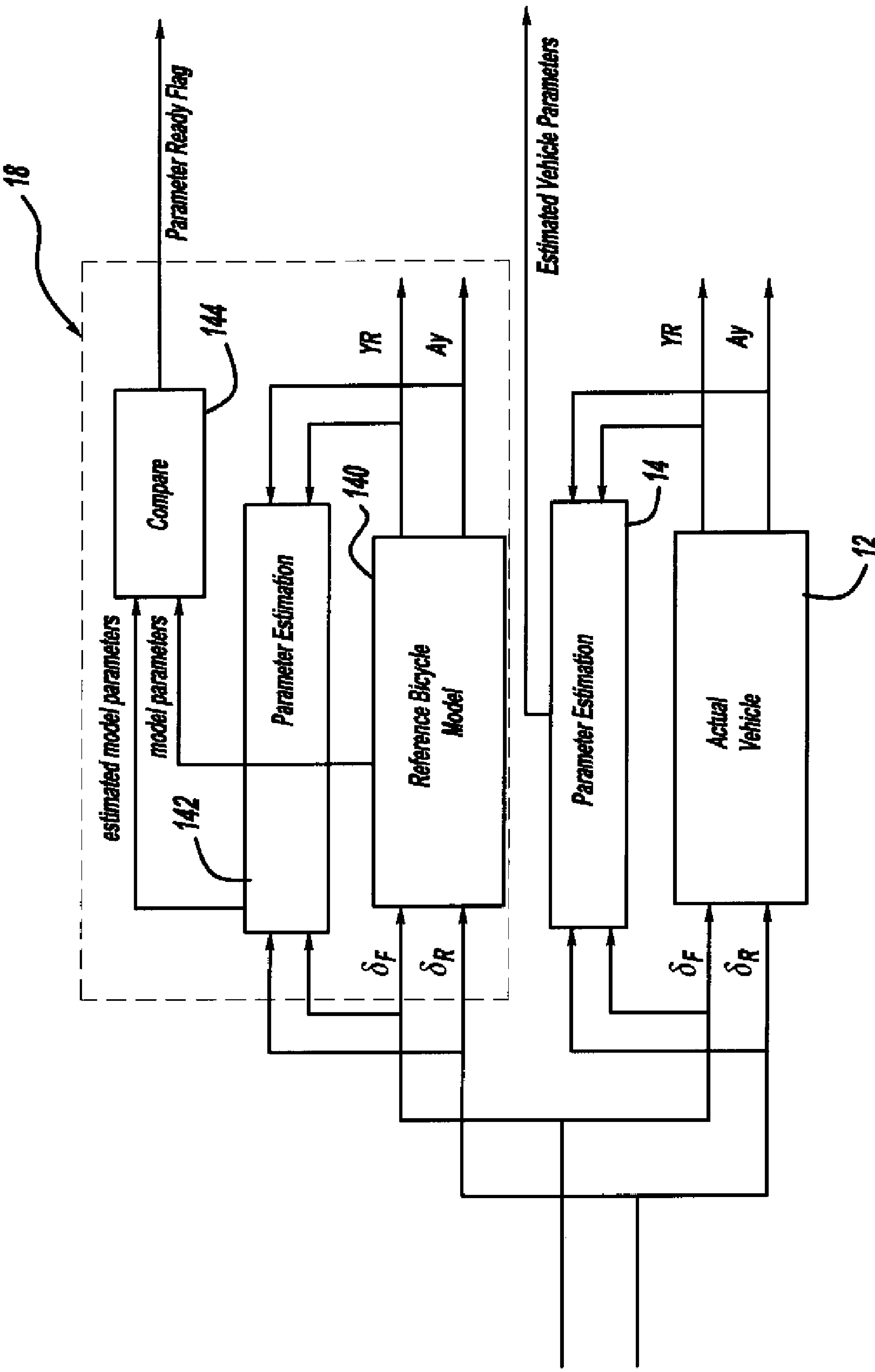

18
Parameter Ready Flag
144
Compare
estimated model parameters
model parameters
Parameter Estimation
142
140
YR
Ay
Reference Bicycle Model
δ_F
δ_R
Estimated Vehicle Parameters
Parameter Estimation
14
YR
Ay
Actual Vehicle
12
δ_F
δ_R

FIG - 6

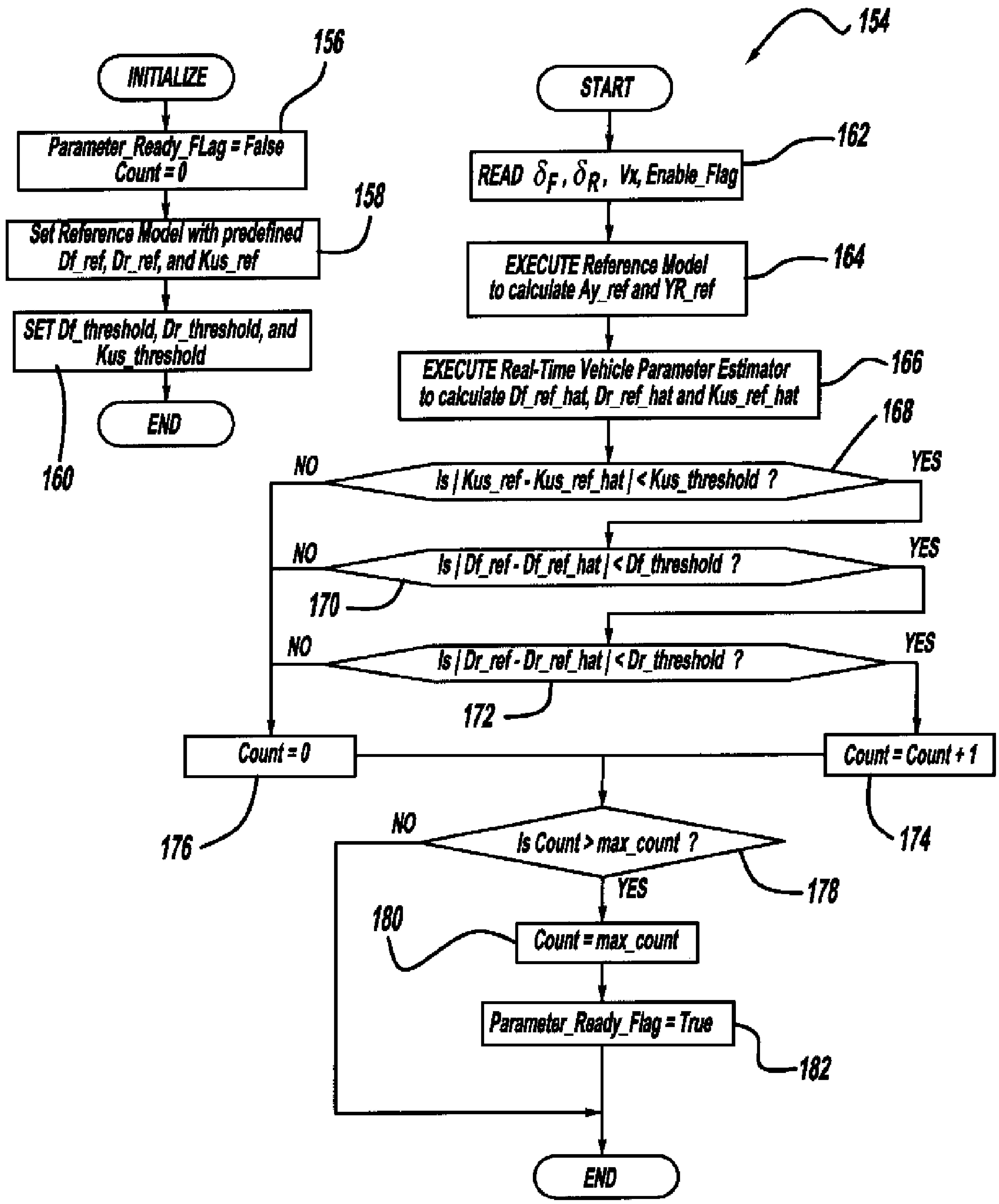

154
156
INITIALIZE
Parameter_Ready_FLag = False
Count = 0
158
Set Reference Model with predefined
Df_ref, Dr_ref, and Kus_ref
SET Df_threshold, Dr_threshold, and
Kus_threshold
END
160
START
162
READ δ_F, δ_R, Vx, Enable_Flag
164
EXECUTE Reference Model
to calculate Ay_ref and YR_ref
166
EXECUTE Real-Time Vehicle Parameter Estimator
to calculate Df_ref_hat, Dr_ref_hat and Kus_ref_hat
168
NO
YES
Is | Kus_ref - Kus_ref_hat | < Kus_threshold ?
NO
YES
Is | Df_ref - Df_ref_hat | < Df_threshold ?
170
NO
YES
Is | Dr_ref - Dr_ref_hat | < Dr_threshold ?
172
Count = 0
Count = Count + 1
176
174
NO
Is Count > max_count ?
YES
178
180
Count = max_count
Parameter_Ready_Flag = True
182
END

FIG - 7

METHOD FOR DETERMINING ESTIMATED VEHICLE DYNAMICS PARAMETERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Divisional application of U.S. patent application Ser. No. 10/863,956, filed Jun. 9, 2004, titled "Real-Time Vehicle Dynamics Estimation System."

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to a method for determining estimated vehicle dynamics parameters and, more particularly, to a method for determining estimated vehicle dynamics parameters that employs a vehicle parameter estimator, a vehicle condition detector and a rich steering input detector for providing an estimated vehicle understeer coefficient, front cornering compliance and rear cornering compliance in real time.

2. Discussion of the Related Art

Vehicles are designed so that the vehicle handling response complies with certain design specifications. Vehicle dynamic parameters define the vehicle handling response, and therefore, nominal parameters define a nominal vehicle handling response. The vehicle dynamic parameters of understeer coefficient, front cornering compliance and rear cornering compliance are the most dominant dynamic parameters for determining the stability and dynamic handling behavior of a vehicle. The understeer coefficient defines the vehicle yaw rate or turning radius for a particular steering angle. The front cornering compliance and the rear cornering compliance define the distribution of the side-slip to the front and rear axle when the vehicle is turning. The cornering compliances include the ratio defined by the steering angle and the lateral force of the wheels. These parameters vary according to different vehicle loading, tire pressure, tire wear, and vehicle-to-vehicle variations of suspension characteristics, etc.

Parameter deviations from the nominal values may cause performance degradation of the chassis/vehicle control systems. For example, as the vehicle ages, the various dynamic parameters change, resulting in a change in the turning radius of the vehicle in response to the same steering angle. It would be desirable to monitor the vehicle dynamic parameters to determine if a problem exists so that suitable steps could be taken. The theory of real-time estimation of a dynamic system is known, and there have been several attempts to estimate vehicle dynamic parameters. The known theories are not feasible enough to be applied to a real vehicle system because they do not properly account for the issues of non-linearity and input richness. These issues can be resolved and the estimation algorithm can be improved.

SUMMARY OF THE INVENTION

In accordance with the teachings of the present invention, a method for determining estimated vehicle dynamics parameters is disclosed that uses a vehicle parameter estimator, a vehicle condition detector and a rich steering input detector for estimating vehicle understeer coefficient and front and rear cornering compliances in real time. The vehicle parameter estimator receives a front wheel steering angle signal, a rearwheel steering angle signal, a vehicle lateral acceleration signal, a vehicle yaw rate signal and a vehicle speed signal, and employs a linear parameter estimation algorithm for estimating the understeer coefficient, the front cornering compliance and the rear cornering compliance. The vehicle condition detector receives the front wheel steering angle signal, the rear wheel steering angle signal, the vehicle yaw rate signal and the vehicle speed signal, and disables the vehicle parameter estimator if the vehicle is not operating in a linear region. The rich steering input detector receives the front wheel angle signal, the rear wheel angle signal and the vehicle speed signal, and provides an output signal indicating whether the estimated parameters are reliable enough.

Additional features of the present invention will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a real-time vehicle dynamics estimation system, according to an embodiment of the present invention;

FIG. **2** is a flow chart diagram illustrating the operation of a vehicle parameter estimator of the system shown in FIG. **1**;

FIG. **3** is a flowchart diagram showing a signal conversion process for the vehicle parameter estimator of the system shown in FIG. **1**;

FIG. **4** is a flow chart diagram showing the operation of a vehicle condition detector of the system shown in FIG. **1**;

FIG. **5** is a flow chart diagram showing a process of linear-region detection for the vehicle condition detector of the system shown in FIG. **1**;

FIG. **6** is a block diagram of a rich steering input detector of the system shown in FIG. **1**; and

FIG. **7** is a flow chart diagram showing the operation of the rich steering input detector shown in FIG. **6**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

The following discussion of the embodiments of the invention directed to a method for determining estimated vehicle dynamic parameters is merely exemplary in nature, and is in no way intended to limit the invention or its applications or uses.

According to the invention, a real-time vehicle dynamics estimation system is provided that estimates a vehicle understeer coefficient and front and rear cornering stiffness by signals from standard dynamic sensor measurements, such as vehicle speed V_X, front wheel steering angle δ_F, rear wheel steering angle δ_R, vehicle yaw rate YR and vehicle lateral acceleration Ay. The real-time vehicle dynamics estimation system of the invention can be combined with a vehicle stability enhancement system using differential braking, active rear-wheel steering, active front-wheel steering or any combination of these systems. Based on the estimations results, the dynamics estimation system can modify the vehicle stability enhancement system to compensate for performance degradation due to vehicle parameter variations, or can send a warning signal to the vehicle operator for maintenance purposes.

FIG. **1** is a block diagram of a real-time vehicle dynamics estimation system **10** for a vehicle **12**, according to an embodiment of the present invention. The system **10** includes a real-time vehicle parameter estimator **14**, a vehicle condition detector **16** and a rich steering input detector **18** all described in detail below. The parameter estimator **14** receives sensor inputs from the vehicle **12** including the front wheel steering angle δ_F, the rear wheel steering angle δ_R, the vehicle lateral acceleration Ay, the vehicle yaw rate YR and the vehicle speed Vx, and generates estimated vehicle dynamics parameter outputs, specifically vehicle understeer coefficient, front cornering compliance and rear cornering compliance. The sensors that provide these measurements are well known in the art, and any sensor suitable for these purposes can be employed. The estimated vehicle parameters can be used by a vehicle controller to provide warning indicators, maintenance indicators, or adapt the vehicle parameters if the vehicle parameters are outside a nominal operating range.

The parameter estimator **14** operates on a linear vehicle model. Therefore, the inputs to the parameter estimator **14** from the various sensors should be from the linear operating region. If the vehicle **12** is out of the linear operating region, the linear correlation between steering and the sensor measurements are not valid, resulting in unrealistic results from the parameter estimator **14**. When the vehicle **12** is not operating in the linear region, the estimator **10** should therefore be disabled. The vehicle condition detector **16** receives the sensor signals of the front wheel steering angle δ_F, the rear wheel steering angle δ_R, the vehicle yaw rate YR and the vehicle speed Vx. The detector **16** processes these input signals to determine if the vehicle **12** is operating in the linear region, and provides an output signal as to whether to enable or disable the parameter estimator **14** and the rich steering input detector **18**.

The conversion of the parameter estimation depends on input excitation. When the input excitation is not rich enough, i.e., the vehicle **12** is not turning frequently enough, the estimated vehicle parameters do not converge to the right value. However, it is difficult for the real-time vehicle parameter estimator **14** to determine whether the estimated vehicle parameters are converged or not. The rich steering input detector **18** receives the front wheel steering angle signal δ_F, the rear wheel steering angle signal δ_R and the vehicle speed Vx, and determines the conversion of the estimated vehicle parameters.

FIG. **2** is a flow chart diagram **26** showing the operation of the real-time vehicle parameter estimator **14**. The estimator **14** initializes theta_hat_**11**, theta_hat_**12**, theta_hat_**21** and theta_hat_**22** to initial values at box **28**. Theta_hat_**11**, theta_hat **12**, theta_hat_**21** and theta_hat_**22** are estimation values produced by a linear parameters estimation algorithm in the parameter estimator **14** to determine the understeer coefficient, rear cornering compliance and front cornering compliance, as will be discussed below. The initial values are predetermined values that give an initial understeer coefficient, an initial front cornering compliance and an initial rear cornering compliance for the original or new design of the vehicle **12**. The estimator **14** then reads the front wheel steering angle δ_F, the rear wheel steering angle δ_R, the vehicle lateral acceleration Ay, the vehicle yaw rate YR, the vehicle speed Vx, and the enable flag from the detector **18** at box **30**. The estimator **14** executes a signal conversion procedure to convert the raw sensor signals into linear regression forms of Y**1**=Phi**1**_vector-theta**1** and Y**2**=Phi**2**_vector-theta**2**, defined below, that are more suitable for the estimation algorithm at box **32**.

FIG. **3** is a flow chart diagram **36** showing the conversion procedure at the box **32**. The estimator **14** initializes a count to zero at box **38**, and reads the sensor signals for the front wheel steering angle δ_F, the rear wheel steering angle δ_R, the lateral acceleration Ay, the vehicle yaw rate YR and the vehicle speed Vx at box **40**. The estimator **14** then divides the lateral acceleration signal by the vehicle speed signal (Ay/Vx) and the vehicle yaw rate signal by the vehicle speed signal (YR/Vx) at box **42**. The front wheel steering angle signal δ_F, the rear wheel steering angle signal δ_R, the lateral acceleration signal Ay, the vehicle yaw rate signal YR, the vehicle speed signal Vx, the Ay/Vx value and the YR/Vx value are input into a bank of low pass derivative filters at box **44**. The derivative filters generate filtered signals, filtered derivative signals and filtered second derivative signals for these values, particularly, Ay_jiltered, Ay_dot filtered, YR_filtered, YR_dot_filtered, YR_2dot_filtered, (Ay/Vx)_filtered, (YR/Vx)_filtered, (YR/Vx)_dot_filtered, δ_F_filtered, δ_F_dot_filtered, δ_R_filtered, and δ_R_dot_filtered at box **44**, where "dot" is the first derivative and "2dot" is the second derivative.

The estimator **14** integrates YR_filtered and (Ay/Vx)_filtered to obtain YR_filtered_integrated and (Ay/Vx)_filtered_integrated at box **46**. The estimator **14** then calculates the regression vectors Phi**1**_vector and Phi**2**_vector and the values Y**1** and Y**2** at box **48** as:

$$Y1=g*(\delta_F\_\text{filtered}+\delta_R\_\text{filtered}-(a+b)*(YR/Vx)\_\text{filtered})$$

$$Phi1\_\text{vector}=\{Ay\_\text{filtered}(t)-Ay\_\text{filtered}(t-\Delta t),\ \text{YR\_dot\_filtered}(t)-YR\_\text{dot\_filtered}(t-\Delta t)\}$$

$$Temp=g*(\delta_F\_\text{filtered}-\delta_R\_\text{filtered}+2*YR\_\text{filtered\_integrated}-2*(Ay/Vx)\_\text{filtered\_integrated}-(a-b)*(YR/Vx)\_\text{filtered})$$

$$Y2=Temp(t)-Temp(t-\Delta t)$$

$$Phi2\_\text{vector}=Phi1\_\text{vector}(t)-\text{Phi1\_vector}(t-\Delta t)$$

$$\text{Delta\_}Y1=Y1(t)-Y1(t-\Delta t) \quad (1)$$

The values a, b and g are the distance from the front axle of the vehicle **12** to the lateral acceleration measurement point, the distance from the rear axle to the lateral acceleration measurement point and a gravitational constant, respectively. Also, (t) denotes current data and (t−Δt) denotes the data from the previous step. The outputs Y**1** and Y**2** and the regression vectors Phi**1**_vector and Phi**2**_vector are used at the box **32** as the converted data to calculate the linear regression forms of Y**1** and Y**2**.

The estimator **14** then determines whether a steady state turning condition is met by comparing the absolute value of Delta_Y**1** with the absolute value of a predefined threshold at decision diamond **50**. It is necessary to detect the steady state condition to handle the bias from Y**1** and Phi**1**_vector. If the stead state condition is met, then Delta_Y**1** will be less than the threshold and should be about zero. The steady state condition must be met continuously for a predetermined period of time. If the steady state condition is met, then the counter is increased by **1** at box **52**, and the estimator **14** determines if the count has reached a predetermined maximum count at decision diamond **54** for this purpose. If the count is greater than the predetermined maximum count, then a steady state flag is set to true at box **56**. If the steady state condition is met, Phi**1**_vector is replaced by Phi**2**_vector. When the steady state is set to true at the box **56**, Y**1** and Phi**1**_vector are recalculated at box **58**. The estimator **14** returns Y**1**, Y**2**, Phi**1**_vector, Phi**2**_vector and the steady state flag at box **64**.

If the count is less than the maximum count, the estimator **14** sets the steady state flag to false at box **60**. Also, if Delta_Y**1** is greater than the predetermined threshold at the decision diamond **50**, meaning no steady state condition, then the count is set to zero at box **62**, and the steady state flag is set to false at the box **60**. For the non-steady state condition, the bias can be removed by using a difference for Y**1** and Phi**1**_vector and, therefore, the original Y**1**, Y**2**, Phi**1**_vector, Phi**2**_vector and the steady state flag are returned at the box **64**.

Returning to FIG. **2**, the estimator **14** then determines if the enable_flag output from the detector **16** is set at decision diamond **70**. If the enable_flag is set to true, then the estimator **14** executes the linear parameter estimation algorithm at box **72** to update the understeer coefficient, the front turning compliance and the rear turning compliance estimates at the output of the estimator **14**. The linear parameter estimation algorithm updates the raw parameters theta_hat_**11**, theta_hat **12**, theta_hat_**21** and theta_hat_**22** using the converted data Y**1**, Y**2**, Phi**1**_vector and Phi**2**_vector. In one embodiment, the linear parameter estimation algorithm employs a recursive least squares algorithm. However, an alternate algorithm, such as a Lyapunov-based algorithm, can be used. The estimated understeer coefficient, defined as Kus_hat, is then set to theta_hat_**11**, the estimated front cornering compliance, defined as Df_hat, is set to (theta_hat_**11** plus theta_hat_**21**)/2 and the estimate rear cornering compliance, defined as Dr_hat, is set to (theta_hat_**21**−theta_hat_**11**)/2 at box **74**. The values Kus_hat, Df_hat and Dr_hat are returned at box **76** at the output of the parameter estimator **14**.

If the enable_flag is not set to true at the decision diamond **70**, then the previous values for theta_hat_**11**, theta_hat_**12**, theta_hat_**21** and theta_hat_**22** are used to calculate the estimated understeer coefficient Kus_hat, the estimated front cornering compliance Df_hat and the estimated rear cornering compliance Dr_hat at the box **74**.

FIG. **4** is a flow chart diagram **80** showing the operation of the vehicle condition detector **16** to determine whether to enable or disable the real-time vehicle parameter estimator **14**. The estimator **14** is only effective when the vehicle **12** is operating in the linear range, i.e., when the vehicle speed Vx is not too low, the vehicle longitudinal acceleration Ax is not too high (accelerating or decelerating to quickly) and the vehicle yaw rate YR is not too great. The detector **16** reads the sensor signals of the front wheel steering angle δ_F, the rear wheel steering angle δ_R, the vehicle yaw rate YR and the vehicle speed Vx at box **82**. The detector **16** calculates a reference yaw rate YR_ref using a command interpreter at box **84** that is used below to determine if the vehicle is in the linear region.

The detector **16** then determines whether the vehicle speed Vx is greater than the absolute value of a minimum speed Vxmin at decision diamond **86**. The vehicle **12** must be traveling greater than a minimum vehicle speed, such as 10 mph, to be operating in the linear region because of kinematics effects. If the vehicle speed Vx is greater than the minimum value Vxmin, then the detector **16** sets a vehicle speed flag Vx_flag to on at box **88**, otherwise it sets the Vx_flag to off at box **90**.

The detector **16** then calculates the vehicle longitudinal acceleration Ax at box **92** using, for example, an FIR filter. The vehicle lateral acceleration Ax cannot be to high to be operating in the linear range. The detector **16** determines whether the vehicle longitudinal acceleration divided by the vehicle speed (Ax/Vx) is less than a predetermined percentage limit at decision diamond **94**. If Ax/Vx is less than the percentage limit, then the detector **16** sets a vehicle longitudinal acceleration flag Ax_flag to on at box **96**, otherwise it sets the vehicle acceleration flag Ax_flag to off at box **98**.

The detector **16** uses a linear region detection filter at box **100** to determine if there is a difference between the vehicle yaw rate YR and the reference yaw rate YR_ref to determine a yaw rate error and indicate whether the vehicle is operating in the linear range. The error due to parameter deviation is usually much smaller than the error due to non-linearity. Therefore, if the error abruptly becomes larger than the specified error, the vehicle **12** is not operating in the linear region. The detector **16** examines the yaw rate error and starts a count if the error is greater than a predetermined yaw rate threshold. When the count value is greater than a predetermined maximum count, the algorithm sets the linear region flag to false.

FIG. **5** is a flow chart diagram **106** showing the operation of the linear region detection filter. The detector **16** first sets a linear region flag (Linear_Region_Flag) equal to true and a count equal to zero at box **108**. The detector **16** then reads the yaw rate signal YR and the yaw rate reference signal YR_ref at box **110**. The detector **16** then determines whether the absolute value of the yaw rate reference signal YR_ref minus the yaw rate signal YR is less than a predetermined yaw rate threshold YR_threshold at decision diamond **112**. If the yaw rate reference signal YR_ref minus the yaw rate signal YR is less than the threshold YR_threshold, the linear region flag stays true, meaning that the vehicle **12** is operating in its linear range, and the count is increased by one at box **114**. If the yaw rate reference signal YR_ref minus the yaw rate signal YR is greater than the yaw rate threshold (YR_threshold), the linear region flag is set to false and the count is left at zero at box **116**.

The detector **16** then determines if the count is greater than a predetermined maximum count at decision diamond **118**. If the count is greater than the maximum count, the detector **16** sets the count equal to the maximum count at box **120**, and sets the linear region flag to true at box **122**. If the count is not greater than the maximum count at the decision diamond **118**, the linear region flag may be true or false, and the algorithm returns to the flow chart diagram **80** in FIG. **4**.

The detector **16** then determines if the linear region flag is set to true at decision diamond **124**. If the linear region flag is set to true, then the linear flag is set on at box **126**, and if the linear region flag is set to false, then the linear flag is set off at box **128**. The detector **16** then sets the enable flag to true only when all of the vehicle speed flag Vx_flag, the vehicle acceleration flag Ax_flag and the linear_region flag are true at box **130**. The detector **16** then outputs the enable_flag at box **132**.

FIG. **6** is a block diagram of the vehicle **12**, the vehicle parameter estimator **14** and the rich steering input detector **18**. The rich steering input detector **18** is used to determine whether the output of the vehicle parameter estimator **14** is reliable enough. If the vehicle **12** is turning frequently enough and is operating in its linear region, then the outputs of the parameter estimator **14** converge to the true parameters. The conversion of the parameter estimation depends on the input excitation. However, it is hard to directly determine the richness of the input excitation so that the estimated parameter is converging to a true value. An indirect way of knowing the convergence of the parameter is to apply the same input to a model with known parameters to generate model outputs, and apply the series of parameter estimation procedures to estimate the parameters of the model. Since the model parameters are already known, determining whether the parameter estimation converges or not can be easily checked by comparing the model parameters and the estimated model parameters.

The rich steering input detector **18** includes a reference bicycle model process block **140**, a parameter estimation process block **142** and a comparison process block **144**. The reference bicycle model process block **140** outputs reference model vehicle parameters based on the front wheel steering angle δ_F and the rear wheel steering angle δ_F. The parameter estimation block **142** determines the same outputs as the parameter estimator **14**, where the estimated model parameters and the reference model parameters are compared in the comparison process block **144**. If the two values are close enough, then the rich steering input detector **18** sets a parameter ready flag to on. The parameter ready flag indicates that the output of the parameter estimator **14** is reliable and ready to be used.

FIG. **7** is a flow chart diagram **154** showing the operation of the rich steering input detector **18**. The input detector **18** first initializes the algorithm by setting the parameter ready flag to false and a count to zero at box **156**; provides the reference model with predetermined reference values for the understeer coefficient Kus_ref, the front cornering compliance Df_ref, and the rear cornering compliance Dr_ref at box **158**; and sets predetermined threshold values for an understeer coefficient threshold Kus_threshold, a front cornering compliance threshold Df_threshold, and a rear cornering compliance threshold Dr_threshold at box **160**.

The detector **18** then reads the sensor signals of the front wheel steering angle δ_F, the rear wheel steering angle δ_R, the vehicle speed Vx, and the enable_flag from the detector **16** at box **162**. The rich steering input detector **18** then executes a reference model algorithm for the reference model **140** to calculate a lateral acceleration reference value Ay_ref and a vehicle yaw rate reference value YR_ref at box **164**. The detector **18** then executes a real time vehicle parameter estimator to calculate estimated reference values for the understeer coefficient Kus-ref_hat, the front cornering compliance Df_ref_hat, and the rear cornering compliance Dr-ref_hat at box **166** as was done at the box **74** for the parameter estimator **14**.

The detector **18** then determines if the absolute value of the difference between the reference understeer coefficient Kus_ref and the estimated reference understeer coefficient Kus_ref_hat is less than the understeer coefficient threshold Kus_threshold at decision diamond **168**; whether the absolute value of the difference between the reference front cornering compliance Df_ref and the estimated reference front cornering compliance Df_ref_hat is less than the front cornering compliance threshold Df_threshold at decision diamond **170**; and whether the absolute value of the difference between the reference rear cornering compliance Dr_ref and the estimated reference rear cornering compliance Dr_ref_hat is less than the rear cornering compliance threshold Dr_threshold at decision diamond **172**. If all three of these comparisons are yes, than the counter is updated by one at box **174**, and if any of these comparisons is no, than the count is set to zero at box **176**.

The detector **18** then determines if the count is greater than a predetermined maximum count max_count at decision diamond **178**. If the count is greater than the maximum count, then the count is set to the maximum count max_count at box **180** and the parameter ready flag is set to true at box **182**. Otherwise the parameter ready flag remains set to false.

The foregoing discussion discloses and describes merely exemplary embodiments of the present invention. One skilled in the art will readily recognize from such discussion and from the accompanying drawings and claims that various changes, modifications and variations can be made therein without departing from the spirit and scope of the invention as defined in the following claims.

What is claimed is:

1. A method for determining estimated vehicle dynamics parameters, said method comprising:

estimating the vehicle parameters using input signals including a front wheel steering angle signal, a rear wheel steering angle signal, a vehicle lateral acceleration signal, a vehicle yaw rate signal and a vehicle speed signal, wherein estimating the vehicle parameters includes using a linear parameter estimation algorithm;

disabling the vehicle dynamics parameter estimation if the vehicle is not operating in a linear region including outputting a disable signal for disabling the vehicle dynamics parameter estimation; and

disregarding the estimated vehicle parameters if a rich steering input condition is not met and the estimated vehicle parameters are not reliable and are not ready to be used including outputting a disregard signal for disregarding the estimated vehicle parameters.

2. The method according to claim **1** wherein estimating the vehicle parameters includes estimating a vehicle understeer coefficient, a front cornering compliance and a rear cornering compliance.

3. The method according to claim **1** wherein estimating the vehicle parameters includes converting the input signals to converted values, executing the linear parameter estimation algorithm based on the converted values to generate estimation values, and calculating the vehicle parameters based on the estimation values.

4. The method according to claim **3** wherein converting the input signals to converted values includes filtering the signals, integrating the signals and generating regression vectors.

5. The method according to claim **1** wherein disabling the estimated vehicle parameters if the vehicle is not operating in a linear region includes disabling the estimated vehicle parameters if the vehicle is not traveling faster than a predetermined speed, the vehicle is accelerating or decelerating faster than a predetermined rate or the vehicle yaw rate is greater than a predetermined yaw rate.

6. The method according to claim **5** wherein determining if the vehicle yaw rate is greater than a predetermined yaw rate includes comparing the vehicle yaw rate to a reference yaw rate.

7. The method according to claim **1** wherein estimating the vehicle parameters includes determining if a steady state turning condition is met.

8. The method according to claim **1** wherein estimating the vehicle parameters includes using an algorithm selected from the group consisting of recursive least squares algorithms and Lyapunov-based algorithms.

9. The method according to claim **1** wherein disregarding the estimated vehicle parameters includes determining a reference model that has pre-defined reference model parameters, providing an estimation of the reference model parameters and comparing the estimation of the reference model parameters to the pre-defined reference model parameters.

10. A method for determining estimated vehicle dynamics parameters, said method comprising:

estimating a vehicle understeer coefficient, a front cornering compliance and a rear cornering compliance using a linear parameter estimation algorithm and input signals including a front wheel steering angle signal, a rear wheel steering angle signal, a vehicle lateral acceleration signal, a vehicle yaw rate signal and a vehicle speed signal;

disabling the vehicle dynamics parameter estimation if the vehicle is not traveling faster than a predetermined speed, the vehicle is accelerating or decelerating faster than a predetermined rate or the vehicle yaw rate is greater than a predetermined yaw rate, wherein disabling the vehicle dynamics parameter estimation includes outputting a disable signal for disabling the vehicle dynamics parameter estimation; and

disregarding the estimated vehicle parameters if a rich steering input condition is not met and the estimated vehicle parameters are not reliable and are not ready to be used, wherein disregarding the estimated vehicle parameters includes determining a reference model that has pre-defined reference model parameters, providing an estimation of the reference model parameters and comparing the estimation of the reference model parameters to the pre-defined reference model parameters, wherein disregarding the estimated vehicle parameters includes outputting a disregard signal for disregarding the estimated vehicle parameters.

11. The method according to claim **10** wherein estimating the vehicle parameters includes converting the input signals to converted values, executing the linear parameter estimation algorithm based on the converted values to generate estimation values, and calculating the vehicle parameters based on the estimation values.

12. The method according to claim **11** wherein converting the input signals to converted values includes filtering the signals, integrating the signals and generating regression vectors.

13. The method according to claim **10** wherein estimating the vehicle parameters includes determining if a steady state turning condition is met.

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